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Study on Effect of Biomineralization and Durability of Concrete

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ABSTRACT

Concrete a greater means in changing the infrastructure of nation through its various applications such as buildings, roadways, bridges etc., fastest growth of concrete construction face parallel failures internally which needs renovation thereby. Microbial growth is one of the recent trends in reinforcing the concrete structures in engineering aspect, thereby increasing the life span. Calcite precipitation is the sealant of micro pores which increases the resistance to deformation and permeability. Several bacteria's were used on the past researches. Combination of bacteria is the new proposal submitted in this study with Lacto Bacillus with Saccromyces and Rhodopseudomonas and the results were compared with conventional concrete and Bacillus Subtilis based microbial concrete. As a standing proof the rod immersed in bacterial solution shows no corrosion than rod immersed in normal water. Advancing on this formulated tests such as Durability Test, Rapid chloride penetration test, Water absorption test, Scanning Electron Microscopy, X-Ray Diffraction were studied. All the experiments concluded that mixture of microbes shows the better performance than individual microbe based concrete with conventional concrete.

Keywords: Lactobacillus spp, Saccharomyces spp and Rhodopseudomonas spp, and Bacillus Subtilis, Durability, Rapid Chloride Penetration, SEM, XRD

I. INTRODUCTION

Concrete is a dependent factor in the construction Industry as it is cheap, easily available and convenient to cast. But concrete weak in tension and strong in compression, so it cracks under sustained loading and due to aggressive environmental agents which ultimately reduce the life of the structure which are built using these materials. Bacteria lives in concrete which are mixed during its casting, found to be dormant still it get contact with water and precipitates calcium carbonate which fills the cracks over the concrete surface during its contact. Oxygen consumption by the bacteria is found to be a positive move since it also reduces the corrosion rate which thereby increases the life span of the structure (Jasira.B., et al., 2016). The capability of concrete in resisting the chemical attacks, weathering action and abrasion by maintaining their engineering properties desired can be seen. Over last decade self-healing approach have been adopted which showed a promising results in the concrete structures. The calcite precipitation inside the concrete beam reduces the permeability of the element, which also improves the strength and durability, no deterioration is found due to the calcite precipitation (Hariharan.H., et al., 2015). Recently, the self-healing approaches have been showing promising results in remediating the cracks in the earlier stages of formation of cracks. On the other hand precipitation of calcite in the concrete specimens by hydro-gel encapsulation, capsules and vascular systems seems to be good at self-healing in the construction activities and researches. Different calcium sources may be adopted for the precipitation of calcite by the continuous hydration of the un-hydrated cement particles in the concrete. Bacterias were also found to even live in high elevated temperatures (Rakesh.C et al., 2014). With the help of calcite precipitation which is a natural and environmental free material which is precipitated during the bacterial activity inside the concrete structure which will plug even small cracks in concrete surface resulting in making a dense concrete with high compressive with stiffness property even in cracked condition (G.T.Suthar et al., 2016). Cracks indicate a smaller scale on durability, through cracks chloride ion penetrates into the structure and start reacting with reinforcement which reduces the p^H value of the surrounding area of steel, also induces the corrosion, since on application of Bacteria in concrete will be a greater barrier in the passage of chloride ion through cracks (Nele.D.B. 2016). MICP (Microbiologically Induced Calcite Precipitation) are used in various applications which increase the financial viability and reduces the production of waste biproducts (Navdeep K.D et al., 2013). Calcite precipitation of ureolytic Bacteria improves the strength, durability. Further it also prevents the process of carbonation in the concrete surface (Kirti.K.S. et al., 2016). The capability of concrete in resisting the chemical attacks, weathering action and abrasion by maintaining their engineering properties desired can be seen. Over last decade self-healing approach have been adopted which showed a promising results in the concrete structures. The durability of the properties refers to trouble-free performance. The addition of bacteria by poly-urethane immobilization and spore formation techniques helps in bonding and crack healing aspects in the concrete. The microbial carbonate precipitation can be obtained by ureolytic activity and the bio-mineralization of the bacteria. The bacteria used are capable of precipitating calcite by producing urea with the help of calcium source. In ordinary Portland cement may not achieve more durability when the structure is constructed in aggressive environment; it's connected to the pore in structure surfaces. More dilapidation in concrete structure is due to the presence of pores. Through this the hostile gases and water penetrate inside the structure that creates physical and chemical reactions. Due to sustainable loading on a structure it causes damages in its surface. The microbial activities its precipitate minerals, this reduces the damages. To enhancing the properties of concrete the bacteria precipitate minerals in concrete surface. Bacteria groups can survive nearly 200 years. Bacterial concrete technique is one of the ways to improve the durability of the concrete structure.

II. METHODS AND MATERIAL

2.1. CEMENT

In this experiment Ordinary Portland cement was used. The cement used for all tests is from the same batch. The cement was tested for various properties as per IS: 4031-1988 and found to be conforming to various specifications of IS: 12269-2009.

2.2. FINE AGGREGATE

The river sand was used as fine aggregate conforming as per IS: 383-1970.The cleaned fine aggregate was chosen and tested for various properties such as specific gravity, finesse modulus, bulk modulus etc...The sand was free from clay, silt and organic impurities and accordance with IS: 2386-1963.

2.3. COARSE AGGREGATE

The crushed angular 20mm size granite was used as coarse aggregate conforming as per IS: 383-1970. Coarse aggregate was tested for various properties such as specific gravity, finesse modulus, bulk modulus etc...In accordance with IS: 2386-1963.

2.4. WATER

The portable water was used for mixing of concrete and curing experiments, conforming to IS: 3025-1964 (part 22 & 23) and IS: 456-2000

2.5. BACTERIA

Bacteria of following type were used
i).Lactobacillus spp, Saccharomyces spp and Rhodopseudomonas spp
ii).Bacillus Subtilis

Bacillus subtilis, known as the **hay bacillus** or **grass bacillus**, is a Gram-positive, catalase-positive bacterium, found in soil and the gastrointestinal tract of ruminants and humans. A member of the genus Bacillus, B. subtilis is rod-shaped, and can form a tough, protective endospore, allowing it to tolerate extreme environmental conditions. B. subtilis has historically been classified as an obligate aerobe, though evidence exists that it is a facultative aerobe. B. subtilis is considered the best studied Gram-positive bacterium

and a model organism to study bacterial chromosome replication and cell differentiation. It is one of the bacterial champions in secreted enzyme production and used on an industrial scale by biotechnology companies.
Medium contains LSR - Lactobacillus spp, Saccharomyces spp and Rhodopseudomonas spp. It has similarity with Bacillus in the mode of action of EM.

2.6. ANTICORROSIVE ACTION BY MICROBES

Past researches literally describe about the anticorrosive work done by the microbes, a test has been conducted in order to visualize the anticorrosive action done by the microbes. A steel rod of 12mm dia rod of considerable length were made to immerse in four different solutions normal water, hardened water, solution with LSR, solution with Bacillus Subtilis for 21days, and as a better proof there is no symbol of corrosive matter in the rods immersed in microbial solution. From fig.1. it can be clearly viewed the formation of corrosion in normal and hardened water in steel rod yet still in normal form while immersed in microbial solution.

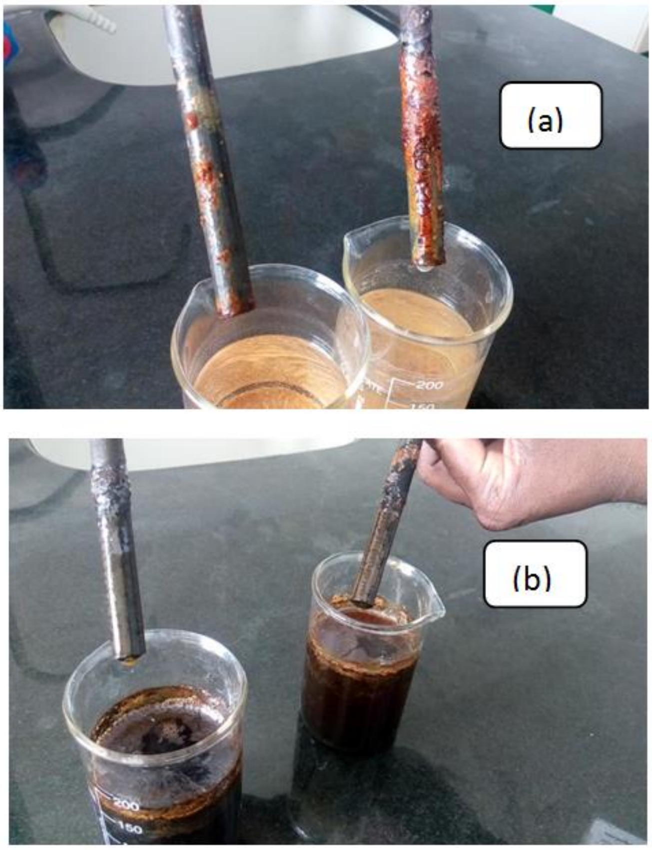

Figure 1. a. steel rod immersed in normal and hardened water.b. rod immersed in microbial solution

2.7. DURABILITY TEST

For the study of durability characteristics of concrete cube with or without bacteria, specimens were immersed in 5% HCL solution and 5% H_2SO_4 Solution, the cubes of size 100mmx100mmx100mm sizes were cast. After 24 hrs the cubes were de-moulded and immersed in water for 28 days. After completion of the period the cubes were taken from the water and cleaned over the surface by dry cloth. The cubes were prepared by using Bacterial (LSR) and Bacillus Subtilis, the concentration of 1x107 cells/ml of water with dosages of 30ml. The specimens were arranged on the container and kept each specimen at a clear distance not less than 30mm. The cubes were immersed in HCL and H_2SO_4 solution for 30days, 45days, 60days, 90days and 120days. After the required period the specimens were dried out of solution and tested against durability. Fig.2. indicates the specimens after immersed in acidic solution. Visibility test was also performed between the normal and microbial concrete to study the microbial growth and deterioration pattern.

Fig.2.Specimens after immersed in HCL and H_2SO_4 solution

2.8. RAPID CHLORIDE PENETRATION TEST (RCPT)

The size of the specimen was 100mm diameter and 50mm thick which was sliced from 100m diameter and 200mm depth of cylinder. Specimen was kept on vacuum for 3Hrs and after that it was immersed in water for 18 Hrs. The specimen was taken from the dessicator and kept the specimen in NaOH (0.3M Concentration) and NaCl(3% Concentration)Solution, switched on the meter and taken the reading from the ammeter, every 30minutes for 6hrs. Nacl solution was filled in one chamber and in another chamber 0.3M of NaOH solution was filled. Fig.3. shows the test setup on rapid chloride penetration. The Chloride ion was forced to migrate through the centrally placed vacuum saturated concrete specimen, under an impressed DC Voltage of 60V. The more permeable the concrete, the higher will be the coloumb, the less permeable the concrete the lower the will be the coloumb.

Fig.3.Rapid Chloride Penetration Test Setup

2.9. WATER ABSORPTION TEST

Specimens were cast to the size of 100mmx100mmx100mm, which is kept in the preheated oven of 135°C for 72hrs. After bone drying the specimens for the required period it was kept out to cool for its own. After attaining the normal temperature the specimens were immersed in water bath. Weights of the specimens were calculated before application of bone drying, after drying and after immersion for 12hrs, 24hrs, 48hrs and 96hrs. Fig.4 a represents the sample bone dried in oven and fig.4.b. represents sample immersed in water. Water percentage was calculated for dosed and non-dosed concrete cubes.

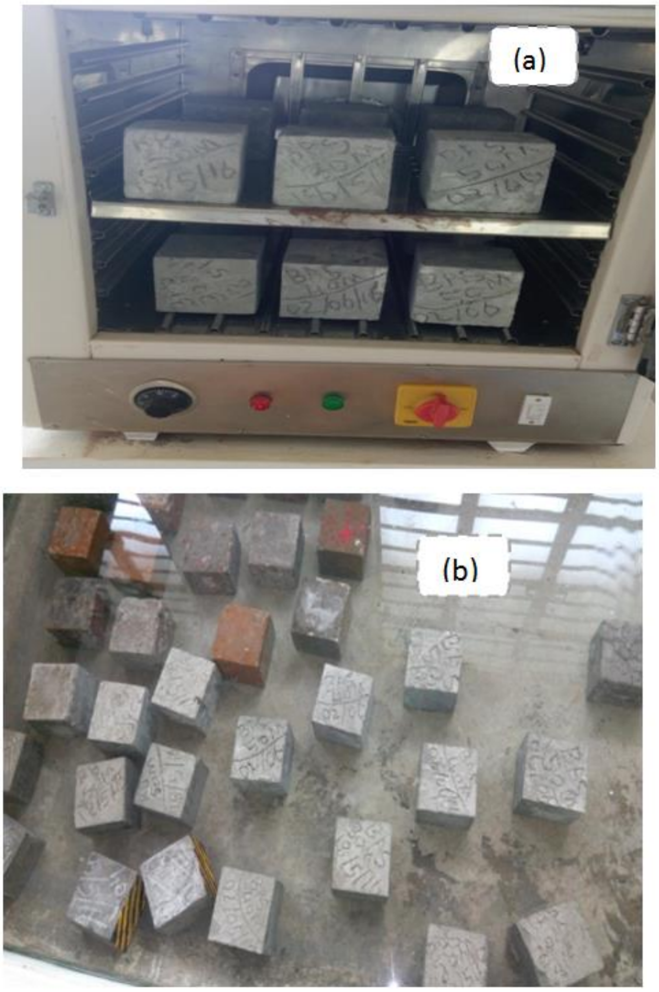

Fig.4. a. Cubes dried in oven b. Cubes immersed in water

2.10. SEM

SEM analysis shows that the growth of microbial activities over the surfaces has quantified. SEM proved the formation of calcite precipitation in microbial concrete.

2.11. XRD

XRD Analysis shows high content of calcite founds in LSR and BS specimens. The percentage of content proves its efficiency of microbial concrete.

III. DISCUSSIONS ON RESULTS

From table.1 and 2, LSR is found to have a lesser fraction in weight and compressive strength loss when compared to all the other specimens (LSR and BC) when immersed in HCL and H_2SO_4 Solution. The lesser the percentage insists the formation of calcite precipitation over the specimen pores which prevented the penetration of water molecules, thereby reinforcing the strength of the specimens. While comparing with the BC specimens, the calcite precipitation is not found to be satisfactory than LSR, less formation of calcite precipitation results in lowering the results and increase in permeability of the specimens.

Graphical representation on weight loss in fig.5 clearly indicates that the gradual fall on BS specimens, while a gradual and a lower raises in LSR specimens, NC specimens were found to have a greater margin more than that of all the other specimens when immersed in HCL solution. In case of fig.6 BS specimens initially started a lower level of loss and finally it coincides with the NC specimen loss, where LSR remains a lesser margin out of other specimens when immersed in H_2SO_4 solution. From fig.7 compressive loss implies that steep falls in BS specimens while LSR moves in a normal range in compressive loss than that of BC and NC specimens when immersed in HCL solution. In Fig.8 all the three specimens have gradually lost their compressive strengths, no particular greater dips were measured. Out of all LSR bear the acidic nature more when immersed in H_2SO_4 solution.

All the results and graphical representation insist that a greater level of precipitation in LSR specimens, which sealed the micro pores thereby directly increasing its resisting property against adverse acidic conditions.

Table 1. Durability Test Results – Weight Loss Comparison (HCL and H_2SO_4 Immersion)

Description	0 Day	Avg.	30 Days	Avg.	45 Days	Avg.	60 Days	Avg.	90 Days	Avg.	120 Days	Avg.
Normal Concrete immersed in HCL Solution												
NC 1	2.606		2.600		2.567		2.421		2.368		2.296	
NC 2	2.644	2.620	2.640	2.615	2.604	2.560	2.465	2.4234	2.398	2.392	2.364	2.296
NC 3	2.610		2.606		2.509		2.420		2.410		2.228	
Bacterial Concrete – Bacillus (30ml) – immersed in HCL Solution												
BS 1	2.600		2.596		2.575		2.555		2.510		2.500	
BS 2	2.516	2.547	2.512	2.543	2.492	2.521	2.461	2.494	2.428	2.455	2.406	2.434
BS 3	2.526		2.523		2.497		2.467		2.427		2.397	
Bacterial Concrete – LSR (30ml)– immersed in HCL Solution												
LSR 1	2.501		2.490		2.470		2.410		2.380		2.310	
LSR 2	2.521	2.518	2.519	2.513	2.510	2.502	2.480	2.470	2.420	2.440	2.380	2.400
LSR 3	2.534		2.530		2.525		2.520		2.516		2.500	
Normal Concrete immersed in H_2SO_4 Solution												
NC1	2.510		2.480		2.440		2.390		2.150		2.050	
NC2	2.560	2.521	2.500	2.480	2.480	2.447	2.400	2.363	2.210	2.187	2.100	2.080
NC3	2.492		2.460		2.420		2.300		2.200		2.090	
Bacterial Concrete – Bacillus (30ml) – immersed in H_2SO_4 Solution												
BS 1	2.506		2.500		2.480		2.45		2.430		2.400	
BS 2	2.488	2.495	2.460	2.480	2.450	2.453	2.420	2.426	2.390	2.405	2.375	2.382
BS 3	2.492		2.480		2.430		2.410		2.395		2.370	
Bacterial Concrete LSR (30ml)– immersed in H_2SO_4 Solution												

LSR 1	2.510		2.48		2.400		2.382		2.275		2.240	
LSR 2	2.570	2.510	2.55	2.490	2.485	2.442	2.472	2.421	2.460	2.362	2.442	2.327
LSR 3	2.451		2.440		2.424		2.410		2.350		2.300	

Table 2. Durability Test Results – Compressive Strength Loss Comparison (HCL and H_2SO_4 Immersion)

Spec.	30 Days		% Loss in Fck	45 Days		% Loss in Fck	60 Days		% Loss in Fck	90 Days		% Loss in Fck	120 Days		% Loss in Fck
	B	A		B	A		B	A		B	A		B	A	
HCL Immersion – Dosage 30 ml															
NC	35.8	34.83	2.71	36.4	30.74	15.55	36.95	30.48	17.51	36.95	27.17	26.47	37.4	26.92	28.02
BC	48.12	47.23	1.85	48.94	45.76	6.50	50.86	45.1	11.33	50.86	45.56	10.42	54	41.83	22.54
LSR	41.6	41	1.44	41.94	40.2	4.15	42.22	39.64	6.11	42.45	38.82	8.55	42.8	35.2	17.76
H_2SO_4 Immersion – Dosage 30 ml															
NC	36.2	33.84	6.52	36.8	30.75	16.44	37.85	29.45	22.19	35.83	26.39	26.35	37.4	25.39	32.11
BC	48.54	46.23	4.76	49.35	42.28	14.33	48.62	40.95	15.78	50.76	40.47	20.27	53.8	39.53	26.52
LSR	41.3	40.53	1.86	40.86	38.5	5.78	41.8	37.05	11.36	41.5	34.47	16.94	41.9	32.45	22.554

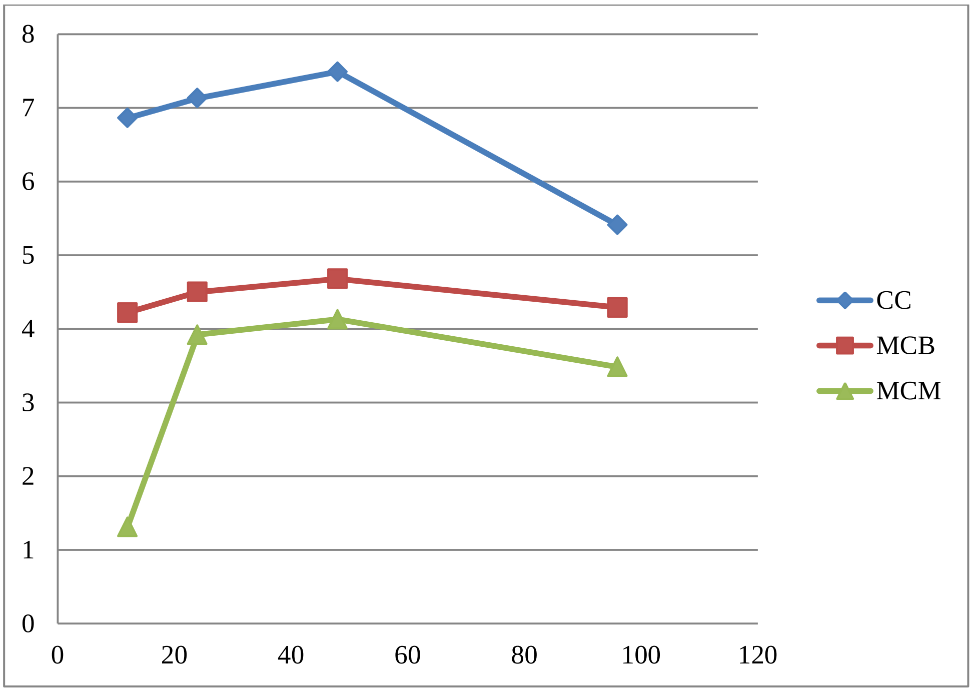

Fig.5. Comparison Chart on Weight Loss in NC, LSR and BS in HCL Solution (Weight loss in Y and Days in X)

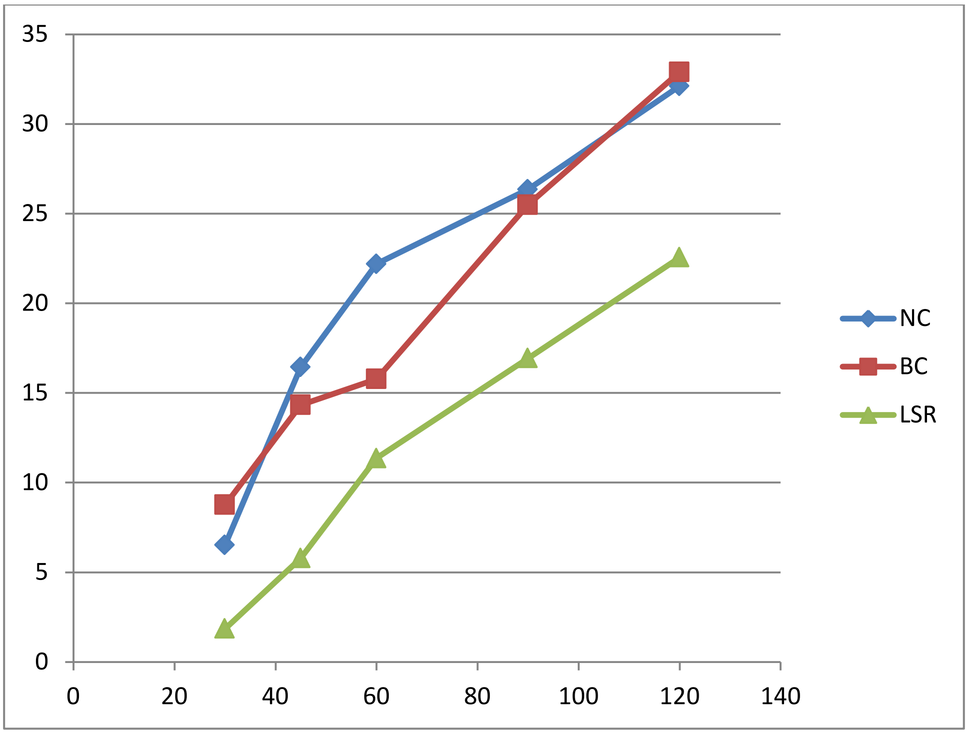

Fig.6. Comparison Chart on Weight Loss in NC, LSR and BS in H_2SO_4 Solution (Weight loss in Y and Days in X)

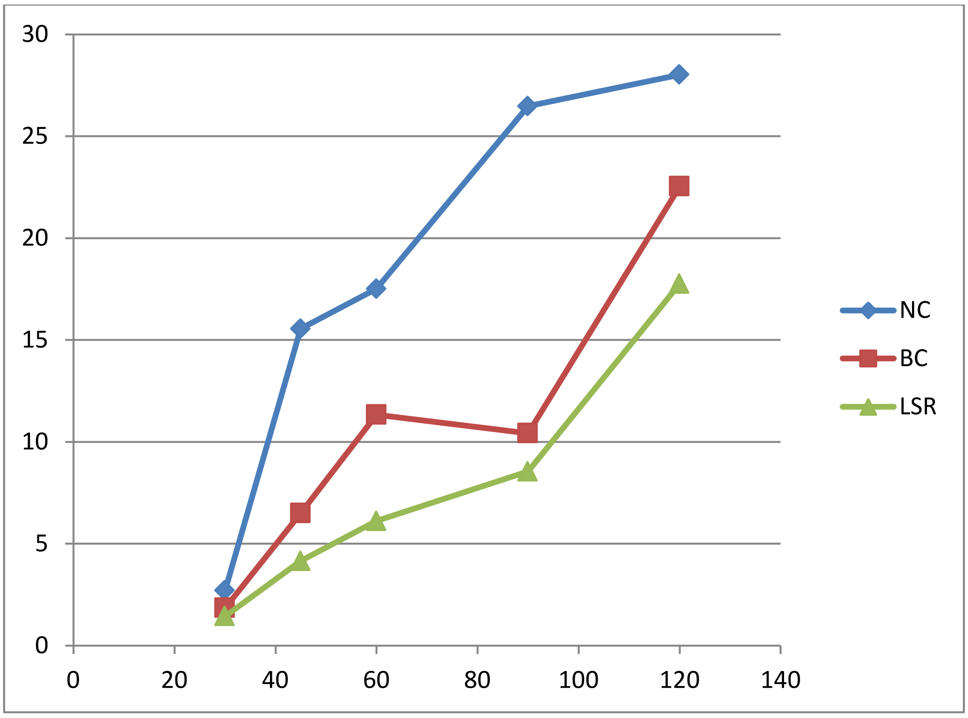

Fig.7. Comparison Chart on Compressive Strength loss in NC, LSR and BS in HCL Solution (Compressive loss in Y and Days in X)

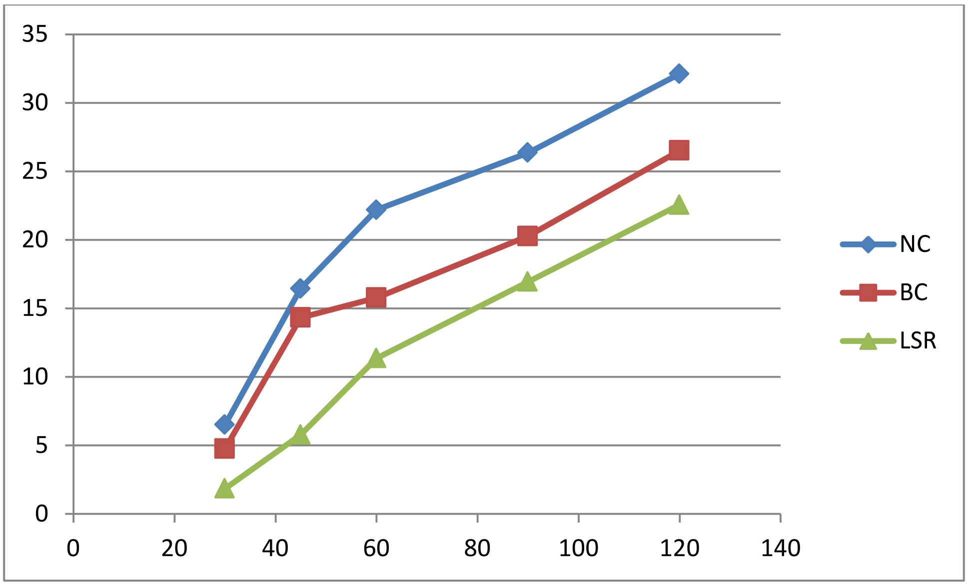

Fig.8. Comparison Chart on Compressive Strength loss in NC, LSR and BS in H_2SO_4 Solution (Compressive loss in Y and Days in X)

From Table.3 RCPT test results it is clearly viewed that the lower the coulomb value for the microbial concrete i.e., BC and LSR when compared to normal concrete. The BC concrete is found to have 5% of lesser coulomb value than normal concrete and LSR is found to have 37% lesser coulomb value than normal concrete which is indicated in fig.9.

Table.3. RCPT Results

Spec.	RCPT Value
NC	1654.5
BC	1571.4
LSR	1200.5

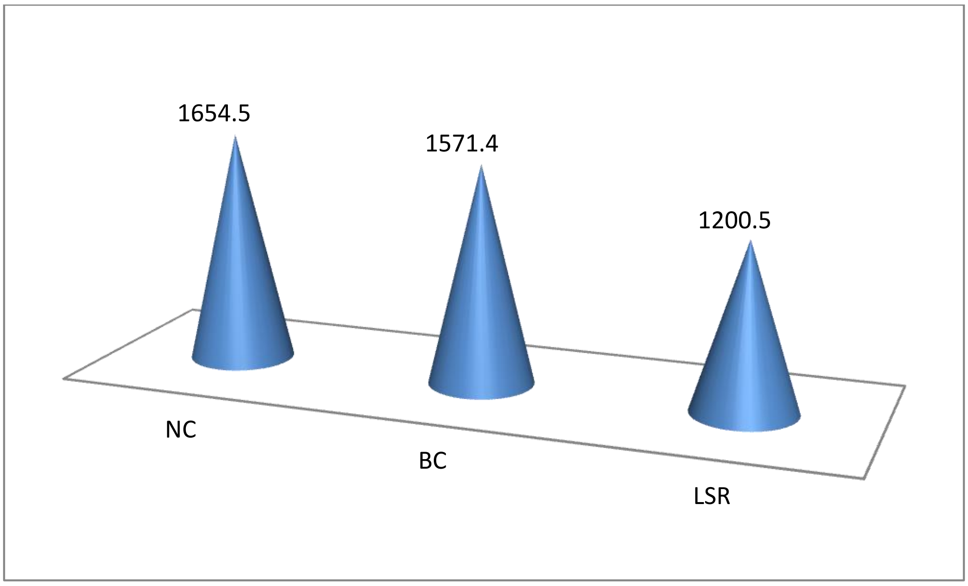

Fig.9.Comparison Chart for RCPT Test

From Table.4. LSR specimens which is dosed with 30ml concentrations shows a relatively lesser ie., 2.88% of water absorption for a period of 12 hrs, when compared to BC (5.58%) and Normal Concrete NC(6.86%), for 24 hrs duration it tends to 5% while that of other were BC (5.79%) and NC(7.13%), for 48 hrs duration it gives a better result of 5.16% while BC fetches 5.95% and NC fetches 7.49%, it is clearly noticed that for the duration of 96hrs it reduced to 3.9% which is again a proving reading which is lesser that BC 4.49% and NC 5.41%. In detail examining the test results it can also be viewed that 96hrs of immersion shows a lesser percentage when compared to the 48hrs of immersion for all the specimens which proves that optimum level of water absorption has made on the 48hrs of immersion itself. While comparing the weight loss before and after the water immersion, it proves that LSR holds the lesser percentage 2.88%, 5%, 5.16% and 3.9% with that of BC 5.58%, 5.79%, 5.95% and 4.49%, NC 6.86%, 7.13%, 7.49% and 5.41%. the test results have plotted in fig.10.

Table.4.Water Absorption test Results

Spec.	Initial Wt.	Weight After							
		12 Hrs	% of WA	24 Hrs	% of WA	48 Hrs	% of WA	96 Hrs	% of WA
NC	2.55	2.725	6.86	2.732	7.13	2.741	7.49	2.688	5.41
BC	2.469	2.607	5.58	2.612	5.79	2.616	5.95	2.580	4.49
RH	2.46	2.531	2.88	2.583	5.00	2.587	5.16	2.556	3.9

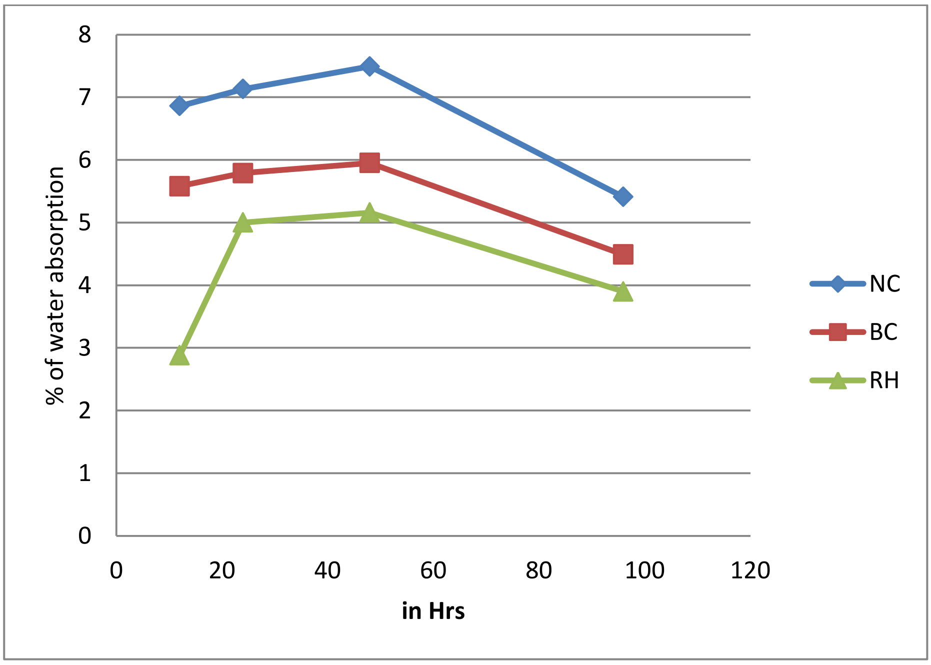

Fig.10. Comparison chart for % of water absorption in Hrs (12, 24, 48, 96)

From Fig.11 a & b, SEM images for LSR shows the formation of calcite precipitation in plate layers while in case of BC images it shows the formation of calcite precipitation in crystal forms. Since the LSR layers are embedded in one on other it gives more strength when compared to BC and Normal Concrete.

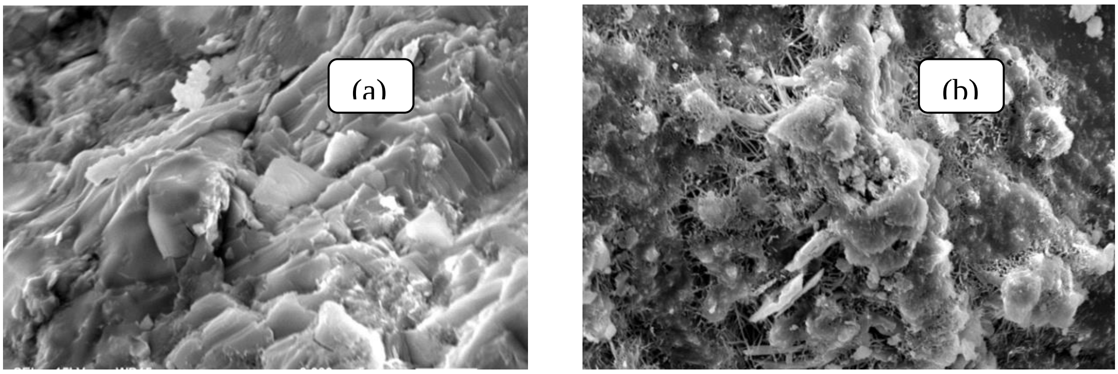

Fig.11. SEM Images showing the Calcite Precipitation LSR and BS Specimens.

From fig.12 XRD of the LSR specimens shows the high content in the formation of Calcium Carbonate content level while in case of BC specimens the amount of formation of Calcium Carbonate content is less which is the reason for the lowering in results in BC.

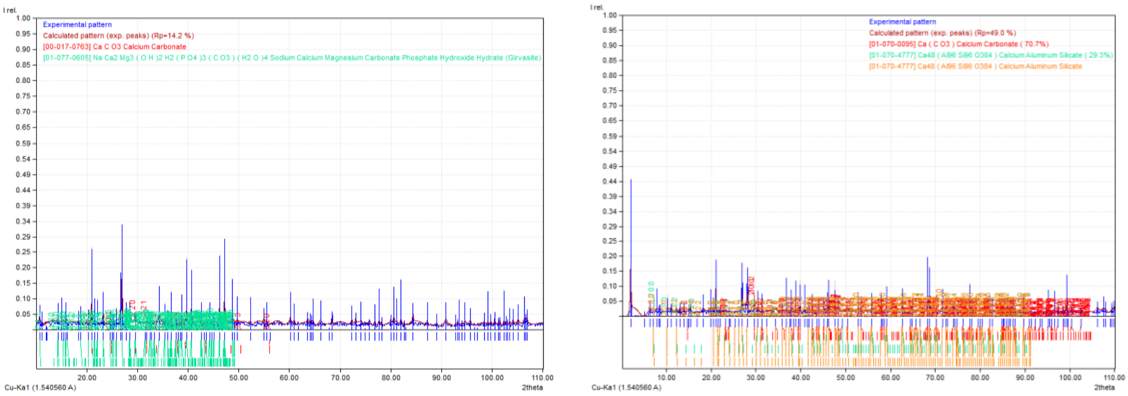

Fig.12. XRD Images of LSR (left) and BS Specimens (Right)

IV. CONCLUSION

The present study implies the following conclusions

- From the present study the combination of microbes LSR specimens gives better result than microbes used individually. The test results insist that calcite formation in LSR is at higher levels while compared to BS specimens.
- This study concludes that combination of microbes will give better durable property than when applied individual.

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